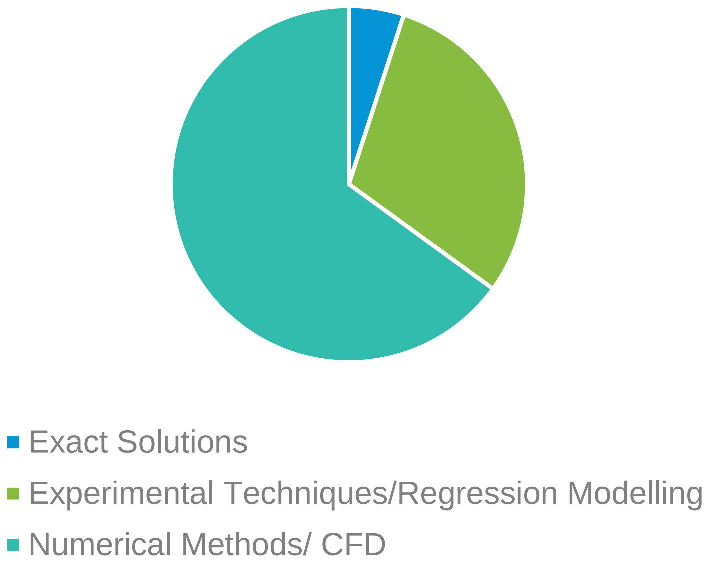
Fluid flow overview

Learning Objectives

- After completing this lesson, you will be able to:
  - Be familiar with the methodologies used to calculate the flow of fluids.

Introduction to fluid flow

- “Fluid” is a generic term used to describe both liquids and gases.
- Fundamental laws such as conservation of mass, momentum and energy provide the equations that underlie these analyses.
- An Equation of State may also be used for finding unknown variables such as density and temperature.
- Complex equations mostly require numerical solutions.



Application of computational fluid dynamics (CFD)

- The diversity of CFD has led to its extensive use in many applications:
  - Process and process equipment
  - Power generation, petroleum and environmental projects
  - Aerospace and turbomachinery
  - Automotive
  - Electronics/appliances/consumer products
  - HVAC/heat exchangers
  - Materials processing
  - Architectural design and fire research

Underlying theory

- Conservation of Energy
  - Energy equation
- Conservation of Momentum
  - Conservative form of Navier-Stokes equation
- Conservation of Mass
  - Continuity equation

- Fluid Pressure and Velocity are the two main variables of interest in fluid flow analysis

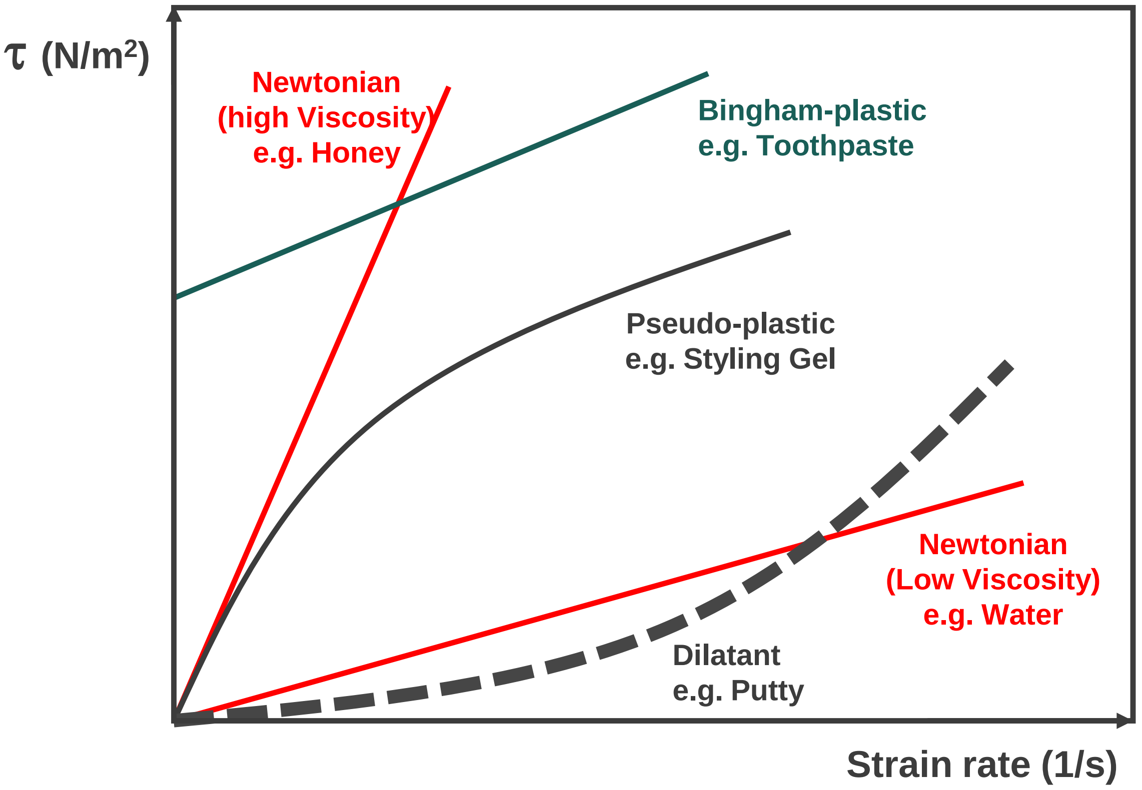
Understanding Viscosity

- Viscosity is the measure of resistance to fluid flow.
- Inviscid fluid is an ideal case in which viscous forces are absent.
- Rarefied flow in the outer atmosphere can be approximated as a real life example of inviscid flow.
- Equations such as the Euler and Bernoulli equations ignore effects of viscosity and thus are restricted to approximate analyses.
- To analyze and predic flow behavior accurately, effects of viscosity cannot be ignored.
- Viscous Fluids can be classified into:
  - Newtonian
  - Bingham
  - Dilatant
  - Plastic

Understanding viscosity

- Fluid viscosity varies in behavior from simple Newtonian fluids to more complex Pseudo-plastic fluids.

- Common engineering fluids are Newtonian.
  - Water
  - Steam
  - Air
  - Oils



Incompressible flow

- Incompressible flow is comparatively easy to solve.
- As density is constant, fluid flow can be solved by continuity and momentum equations alone.
- For all practical cases, air flow with Mach number below 0.3 can be treated as incompressible.
    - Although no liquid is truly incompressible, it is a very accurate approximation.

Compressible flow

- For compressible flow, as density is variable, the energy equation needs to be introduced, which relates density to temperature.

- To solve for both these additional variables (density and temperature), a separate equation is also required.

- The Boussinesq approximation or Equation of State can be used to relate density and temperature (ρ, T)

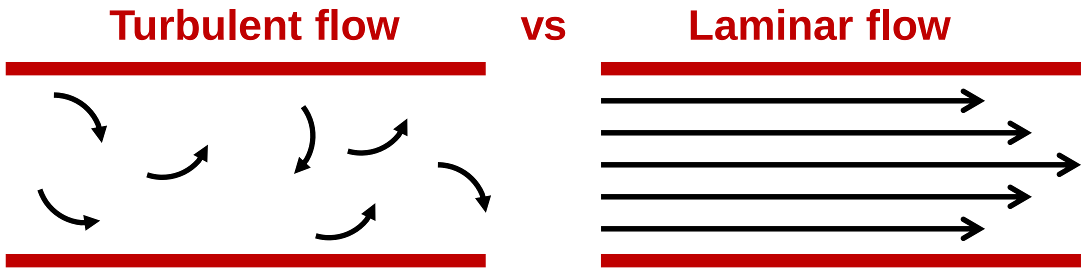
$$\rho = \rho_o\left[1 - \alpha(T - T_o)\right]$$

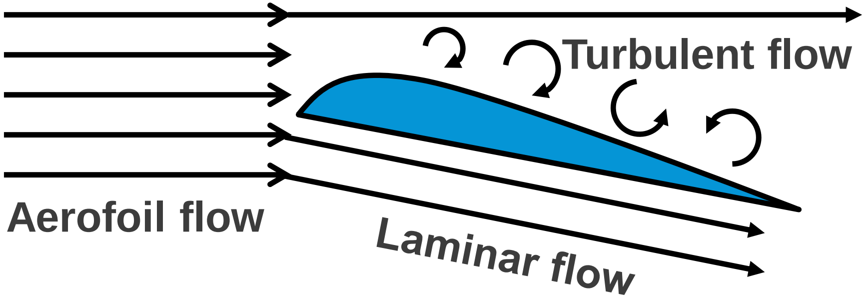
Where:
α is the coefficient of volume expansion.
ρ_o is the known value of density at temperature T_o

- The study of sound waves in air and choked flow in a converging diverging nozzle are common examples of compressible flow.

Types of flow

- Compressible vs. Incompressible
- Laminar vs. Turbulent
- Steady vs. Unsteady





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